PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 08 November 2000 (08.11.00)	
International application No. PCT/GB00/01164	**Applicant's or agent's file reference** P22384A/GMM/
International filing date (day/month/year) 27 March 2000 (27.03.00)	**Priority date** (day/month/year) 26 March 1999 (26.03.99)
Applicant LOXLEY, Neil et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

29 September 2000 (29.09.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740 14 35	Authorized officer Olivia TEFY Telephone No.: (41-22) 338 83 38

PATENT COOPERATION TREATY

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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
P22384A/GMM/		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/ 01164	27/03/2000	26/03/1999
Applicant		
BEDE SCIENTIFIC INSTRUMENTS LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in th international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has be n furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within on month from th date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawing** to be publish d with the abstract is Figure No. 1

   [X] as suggested by the applicant.

   [ ] because th applicant failed to suggest a figure.

   [ ] because this figure better characterizes th invention.

   [ ] Non of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01164

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01J35/14 H01J35/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 631 742 A (OLIVER DAVID W) 23 December 1986 (1986-12-23) column 1, line 50 -column 2, line 37;	1
Y	figure 1 column 4, line 10-34	8-11
X	US 4 748 650 A (AMMANN ERNST) 31 May 1988 (1988-05-31) column 1, line 15-68; figures 1,2	1
Y		8-11
Y	WO 98 13853 A (ARNDT ULRICH WOLFGANG ;BEDE SCIENT INSTR LTD (GB); DUNCUMB PETER ()) 2 April 1998 (1998-04-02) claims 1,7,8	8-11

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 July 2000	26/07/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Centmayer, F

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01164

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 689 809 A (SOHVAL A ROBERT) 25 August 1987 (1987-08-25) abstract figures 1,2	1
A	EP 0 473 852 A (IMATRON INC) 11 March 1992 (1992-03-11) column 7, line 43-51; figure 5 column 8, line 24-34	1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

'ormation on patent family members

International Application No
PCT/GB 00/01164

Patent document cited in search report	Publication dat	Patent family member(s)	Publication dat
US 4631742 A	23-12-1986	NONE	
US 4748650 A	31-05-1988	DE 3401749 A	01-08-1985
		DE 3470361 D	11-05-1988
		EP 0150364 A	07-08-1985
WO 9813853 A	02-04-1998	AU 4313197 A	17-04-1998
		EP 0928496 A	14-07-1999
US 4689809 A	25-08-1987	DE 3342127 A	07-06-1984
		FR 2536583 A	25-05-1984
		IL 70210 A	20-10-1987
		IT 1178354 B	09-09-1987
		JP 1731584 C	29-01-1993
		JP 4015982 B	19-03-1992
		JP 59149642 A	27-08-1984
		NL 8304028 A,B,	18-06-1984
EP 0473852 A	11-03-1992	US 4993055 A	12-02-1991
		US 5105456 A	14-04-1992

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

Murgitroyd & Company
373 Scotland Street
Glasgow G5 8QA
GRANDE BRETAGNE

MURGITROYD & COMPANY
06 AUG 2001
COMP GMM

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

Date of mailing *(day/month/year)*	02.08.2001
Applicant's or agent's file reference P22384A/GMM/GMU	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/01164	27/03/2000	26/03/1999

Applicant
BEDE SCIENTIFIC INSTRUMENTS LIMITED et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Schuster-Kaechele, W Tel.+49 89 2399-2281

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P22384A/GMM/GMU		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/01164	27/03/2000	26/03/1999
International Patent Classification (IPC) or national classification and IPC H01J35/14		
Applicant BEDE SCIENTIFIC INSTRUMENTS LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 9 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 4 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
29/09/2000	02.08.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Telephone No. +49 89 2399

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/01164

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-14	as originally filed				

Claims, No.:

1-13	as received on	02/03/2001	with letter of	02/03/2001	

Drawings, sheets:

1/3-3/3	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

☐ restricted the claims.

☐ paid additional fees.

☐ paid additional fees under protest.

☐ neither restricted nor paid additional fees.

2. ☒ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

☐ complied with.

☐ not complied with for the following reasons:

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

☒ all parts.

☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims 1-4,6-10,12,13
	No:	Claims 5
Inventive step (IS)	Yes:	Claims 1-4,12
	No:	Claims 13

Industrial applicability (IA) Yes: Claims 1-13
No: Claims

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Reference is made to the following documents:

D1: US-A-4 631 742
D2: US-A-4 748 650
D3: WO-A-98/13853
D4: JP-A-10340695
D5: US-A-5 857 008

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. D1 (see in particular the places indicated in the Search Report) describes an X-ray generator comprising a electron gun (12), electron focussing means (16), a target (18) and electronic control means (52) , wherein the area of the target on which the focussing means causes electrons from said electron gun to impinge forms an X-ray source. The control means includes a switching means to switch the electron focusing means between a first unfocused state in which the X-ray source has a first area and second focused state in which the X-ray source has a second area smaller than the first area.
D4 describes an X-ray generator comprising a shutter (7) to control the emitted X-ray beam.
The problem to be solved by the present invention may be regarded as providing means to lengthen the life of the X-ray generator by reducing the degradation of the target in periods in which the X-ray beam is not required (see page 3. lines 5-17, page 9, line 26 to page 10, line 5).

This is obtained by the X-ray generator according to claim 1 and the method according to claim 11 in that the shutter is closed when the X-ray beam is not required and, at the same time, the electron beam is defocused such that the area

on the target which forms the X-ray source is large. This way the heat load on the target, when the X-ray beam is not required, is reduced.
D1 teaches the defocusing of the electron beam on start-up of an X-ray generator until the target has reached the desired temperature. It does not concern a stand-by operation when the X-ray beam is not required.

The solution to the problem proposed in claims 1 and 11 of the present application is considered new (as Article 33(2) PCT) and involving an inventive step (Article 33(3) PCT) because it is not known from any of the documents cited in the Search Report nor is it suggested by these documents.

2. Claims 2-4, 6-10 and 12 are dependent on claims 1 or 11 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

3. D2 (see in particular the places indicated in the Search Report) describes an X-ray generator comprising a electron gun (1), electron focussing means (3), a target (2) and electronic control means (9,11), wherein the area of the target on which the focussing means causes electrons from said electron gun to impinge forms an X-ray source. The control means are adapted to control deflection means so that the X-ray source on said target may be varied in shape and/or size. The control means includes a switching means (see in particular figure 4) to switch between a plurality or states, the X-ray source having a particular size and/or position (see col. 2, lines 47-62) .It is proposed in D2 to vary the size/position in stages. For a certain period of time thereby the X-ray source is in a stationary position (see fig. 2).
Therefore, the X-ray generator according to claim 5 is not new (Art. 33 (2) PCT).

4. Dependent claims 6-10 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step, the reasons being as follows:
The skilled person can choose appropriate sizes of the source areas within his normal non-inventive activity.
x-y deflection systems for centring the electron beam and electron lenses are well known in combination with X-ray tubes.
Quadrupole or multipole electron lenses for focussing the electron beam to a line

focus and for steering the electron beam are known from D3.
The materials stated in claim 10 are normal target materials for X-ray tubes and e.g also mentioned in D3.

5. The concept of using a fresh area of the target when one area has degraded is known from D5 (see in particular col. 3, line 45 to col, 4, line 4 and figure 1). For each area, the position of the electron beam on the target is stationary. It is evident for a person skilled in the art the areas should not overlap and that a particular position of the electron beam on the target can be obtained by moving either the target of the electron beam.
The skilled person would therefore regard it a normal design procedure to combine features known from D2 with features known from D5.

Thus, the subject-matter of claim 13 does not involve an inventive step and does not satisfy the criterion set forth in Article 33(3) PCT.

Re Item VII
Certain defects in the international application

1. The description has not been brought in line with the amended claims. The more general statements in the description on page 9, line 26 to page 10, line 5 and page 11, line 22 to page 12, line 5 imply that the subject-matter for which protection is sought may be different to that defined by the claims, thereby resulting in lack of clarity (Article 6 PCT) when used to interpret them (see also the PCT Guidelines, III-4.3a).

2. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1, D2, D4 and D5 is not mentioned in the description, nor are these documents identified therein.

Re Item VIII

Certain observations on the international application

The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

Re Item IV

Lack of unity of invention

The separate inventions/groups of invention are:
1. Claims 1-4, 11,12 and 6-10 as dependent on claim 1
2. Claims 5, 13 and 6-10 as dependent on claim 5

With regard to D2, the "special technical features" of claims 1 and 11 are:
a shutter and defocusing of the electron beam upon action of this shutter.
Claims 5 does not include any "special technical features" (see item V, point 3).
The features of claims 6-10 as dependent on claim 5 do not have anything in common with the "special technical features" of claims 1 and 11.
"Special technical feature" of claim 13 is : no overlap between discrete positions.
This "special technical feature" is also different from the "special technical features" of claims 1 and 11.
The requisite unity of invention (Rule 13.1 PCT) therefore does not exists inasmuch as a technical relationship involving one or more of the same or corresponding special technical features in the sense of Rule 13.2 PCT does not exist between the subject-matter of groups 1 and 2.

Observation as to the disclosure of the subject-matter of amended claims

Claims 1 and 11 correspond to claims 1 and 2 or 12 and 13 as originally filed, with the addition of the feature that the electron beam is defocused upon activation of the shutter, which has a basis at page 9, line 34 to page 10, line 5.
Claims 5 and 13 correspond to claims 1 and 6 or 14 as originally filed , with the addition

of the feature that the corresponding discrete position of the target is stationary, the basis for this feature can be found at page 11, line 22 to page 12, line 5 of the application as filed.
Claims 2 to 4 correspond to original claims 3 to 5 and claims 6 to 10 correspond to original claims 7-11.

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H01J 35/14, 35/30 — A1

(11) International Publication Number: WO 00/58991

(43) International Publication Date: 5 October 2000 (05.10.00)

(21) International Application Number: PCT/GB00/01164

(22) International Filing Date: 27 March 2000 (27.03.00)

(30) Priority Data:
9906886.8 26 March 1999 (26.03.99) GB

(71) Applicant *(for all designated States except US)*: BEDE SCIENTIFIC INSTRUMENTS LIMITED [GB/GB]; Bowburn South Industrial Estate, Bowburn, Durham DH6 5AD (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: LOXLEY, Neil [GB/GB]; 9 Whitesmocks Avenue, Durham DH1 4HP (GB). TAYLOR, Mark [GB/GB]; 71 Salutation Road, Darlington DL3 8JW (GB). WALL, John, Leonard [GB/GB]; 34 Cheltenham Way, Newton Aycliffe DL5 4YD (GB). FRASER, Graham, Vincent [GB/GB]; Whitehouse Farm Cottage, Heighington, Darlington DL2 2XQ (GB).

(74) Agent: MURGITROYD & COMPANY; 373 Scotland Street, Glasgow G5 8QA (GB).

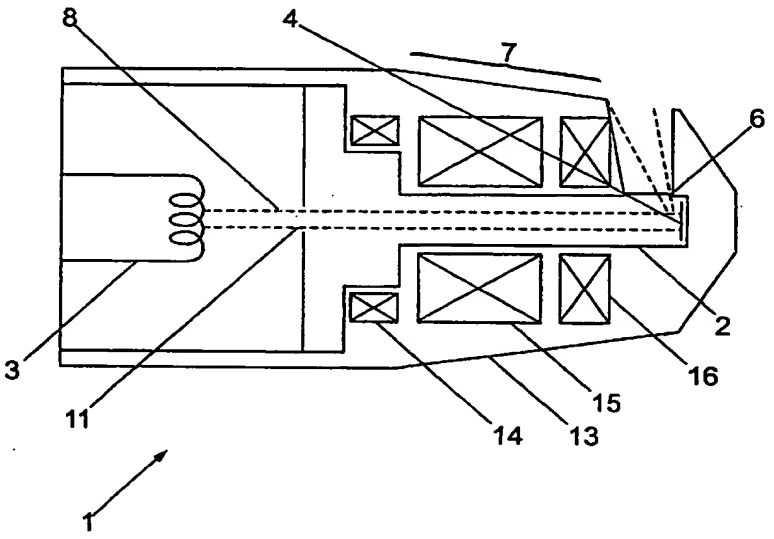
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

With international search report.

Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD AND APPARATUS FOR PROLONGING THE LIFE OF AN X-RAY TARGET



(57) Abstract

An X-ray generator (1) comprises an evacuated and sealed X-ray tube (2), containing an electron gun (3) and an X-ray target (4). An electron beam is produced by the electron gun (3) in which the cathode is at negative high voltage, the electron gun (3) consisting of a filament just inside the aperture (11) of a Wehnelt grid which is biased negatively with respect to the filament. Two sets of beam deflection coils (14), are employed in two planes, mounted between the anode of the electron gun (3) and the focussing lens (15) to centre the beam. Between the focussing lens (15) and the target (4) is an air-cored quadrupole magnet which acts as a stigmator (16) in that it turns the circular cross-section of the beam into an elongated one. This quadrupole (16) can be rotated about the tube axis so as to adjust the rientation f the line focus. The beam can be moved about n the target surface (4) by controlling the currents in the four coils of the quadrupole (16).

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
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Method and Apparatus for Prolonging the Life of an X-Ray Target

This invention relates to an X-ray generator, and in particular to apparatus for prolonging the life of an X-ray target used within an X-ray generator.

Known X-ray generators comprise an electron gun, an X-ray target and an X-ray exit window. These generators produce X-rays by accelerating electrons from the electron gun into the x-ray target. X-rays are emitted from the target through the exit window. Such generators may be in the form of sealed X-ray tubes, for example microfocus tubes, which are evacuated once and then sealed off, or in the form of rotating anode generators, which are permanently connected to vacuum pumps and are continuously evacuated during operation.

A major limitation to the longevity of X-ray generators is the lifetime of the target. All targets degrade over time due to the effects of heat and roughening caused by the electron bombardment. There are various known methods for reducing these effects, including cooling the back of the target with flowing water or rotating the target so that no one area of the target is continuously subjected to the electron bombardment.

Methods of increasing the cooling efficiency have been proposed based on using high conductivity materials such as diamonds. However, these methods are not in common usage currently.

With known X-ray generators, it can take a number of minutes after switching on the machine before it has stabilised and is ready for use. As a result, many generators are simply left running throughout the day, so that the "warm-up" or stabilisation delay is removed. This means that the electrons are focussed on the target for long periods of time during each use of the generator, which leads to accelerated degradation of the target, even though the radiation produced by the X-ray generator is used only for short periods.

In cases where the construction of the generator permits, the target can be replaced. Where the construction does not permit target replacement in a routine procedure, then it is common practice to discard the complete tube assembly making up the X-ray generator.

In commercially available sealed tube and rotating anode generators, there is no provision to control the position of the beam on the target or to control the quality, size or shape of the focal spot on the X-ray target. The quality of the X-ray beam emitted can deteriorate rapidly with prolonged use due to contamination and damage to the target area under continuous electron bombardment.

In the case of rotating anode generators, once performance has degraded below a useful level, replacement of the target is required. This entails cost of replacement parts as well as significant down

time of the generator. In the case of sealed tube generators t is necessary to discard the whole tube and replace it with a new tube.

It is an object of the present invention to provide means to lengthen the life of a target, and thereby to lengthen the life of the X-ray generator. By controlling the position and brightness of the beam, the apparatus according to the present invention can reposition and modify the area of focus of the beam. Defocussing the beam reduces the flux per unit area of electrons on the target. Repositioning the beam enables a fresh area of the target to be exposed to electrons. The lifespan of the target is prolonged by either of these means, and the time interval between replacements of the target or of the complete tube assembly is increased.

A consequence of the approach of the present invention is that the tube is only required to run in operational condition with the target exposed to focussed electrons when the operator requires the X-ray beam to be produced.

According to the present invention, there is provided an X-ray generator comprising an electron gun, electron focussing means, a target and electronic control means, wherein the area of the target on which the focussing means causes electrons from said electron gun to impinge comprises an X-ray source, the control means being adapted to control the electron focussing means so that the X-ray source on said target may be varied in size and/or shape and/or position.

According to a first aspect of the invention the control means includes a switching means to switch the

electron focussing means between a first unfocussed state in which the X-ray source has a first area and a second focussed state in which the X-ray source has a second area smaller than said first area. The second area may be a line, a spot or some other profile. The first area may be a line of greater thickness, a spot of greater diameter or some other shape.

Preferably said first area has a surface area at least twice, more preferably four times, most preferably ten times that of said second area.

According to a second aspect of the invention the control means includes a switching means to switch the electron focussing means between a plurality of focussed states, whereby in each state the X-ray source is in a corresponding discrete position on said target. The X-ray source may be in the form of a line, a spot or some other profile on the target.

The electron gun may comprise an evacuated tube around which the electron focussing means is mounted outside the vacuum. Alternatively the electron gun may comprise an evacuated tube within which the electron focussing means is mounted. The evacuated tube may be a sealed vacuum tube or may be connected to a vacuum pump which permits continuous evacuation during operation of the generator.

The electron focussing means may comprise an x-y deflection system for centring the electron beam in the tube. The electron beam focussing means may further comprise at least one electron lens, preferably an axially symmetric or round lens, and/or at least one quadrupole or multipole lens for focussing the electron beam to a line focus and for steering the electron

beam.

The electron beam lenses may be magnetic or electrostatic.

Preferably the target is metal, most preferably a metal selected from the group Cu, Ag, Mo, Rh, Al, Ti, Cr, Co, Fe, W, Au. The target surface may be orientated such that the plane of the target surface is perpendicular or at an angle to the axis of the X-ray tube.

According to a third aspect of the present invention there is also provided a method for extending the life of a target of an X-ray generator, wherein the generator comprises an electron gun, electron focussing means and a target, the method comprising the steps of: firing electrons at the target such that the area of the target on which the focussing means causes electrons from said electron gun to impinge comprises an X-ray source,
controlling the electron focussing means to move between a first unfocussed state in which the X-ray source has a first area and a second focussed state in which the X-ray source has a second area smaller than said first area, the intensity of electron impingement in the first state being sufficiently low to reduce target degradation, the intensity of electron impingement in the second state being sufficiently high such that the source produces a predetermined required level of brightness and source size on the target. The source may be a spot, a line or some other profile.

Preferably the electron beam current is substantially the same in the first and second states, while the intensity of the beam per unit area at the target is lower in the first state than in the second state.

According to a fourth aspect of the present invention there is provided a method for extending the life of a target of an X-ray generator, wherein the generator comprises an electron gun, electron focussing means and a target, the method comprising the steps of:
firing electrons at the target such that the area of the target on which the focussing means causes electrons from said electron gun to impinge comprises an X-ray source,
controlling the electron focussing means to move between a plurality of focussed states, whereby in each state the X-ray source is in a corresponding discrete position on said target, such that the intensity per unit area in each discrete position is substantially constant, and such that there is no overlap on the target between the discrete positions corresponding to each focussed state. The source may be a spot, a line or some other profile.

The lack of overlap between the discrete positions on the target means that a fresh area of target is used as a source each time the electron focussing means moves to a new state. The control of the electron focussing means may be manual but is preferably electronic, so that each discrete position corresponds to a pre-programmed control signal applied to the electron focussing means.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying figures, where:

Fig. 1 shows a schematic longitudinal section through an X-ray generator according to the invention suitable for use with a close coupled X-ray focussing system (not shown);

Fig. 2 shows a schematic arrangement of an X-ray generator in the focussed state;

Fig. 3 shows a schematic arrangement of an X-ray generator in the defocussed state;

Fig. 4 shows a schematic arrangement of an X-ray generator with the target in a first focussed position;

Fig. 5 shows a schematic arrangement of an X-ray generator with the target in a second focussed position;

Figs. 6(a) and 6(b) shows schematically a side view and plan view respectively on a sealed tube X-ray generator according to the invention; and

Figs. 7(a) and 7(b) shows schematically a side view and front view respectively on a rotating anode X-ray generator according to the invention.

With reference to Fig. 1, the X-ray generator 1 comprises an evacuated and sealed X-ray tube 2, containing an electron gun 3 and an X-ray target 4. The tube 2 has an exit window 6 through which X-rays are emitted from the target. Although the embodiment illustrated in Fig. 1 has a window 6 in front of the target 4, it is to be understood that the invention is applicable to other embodiments, for example X-ray generators in which the X-rays are emitted behind the target 4. The exit window does not form part of the invention and is not further described.

The tube 2 is contained within a housing 13. The generator 1 also includes a system 7 for focussing and

steering the electron beam 8 onto the target 4.

The focussing and steering system is capable of producing a well focussed beam of electrons 8 impinging on the target 4. The electron beam 8 may be focussed into a spot or a line, and the dimensions of the spot and line as well as its position may be changed electronically. In typical X-ray applications a spot focus having a diameter falling in the range 1 to 100 μm, generally 5 μm or larger, may be required. Alternatively a line focus may be achieved whose width falls in the range 0.4 mm to 1.0 mm, and length in the range 5 mm to 15 mm.

The electron beam 8 is produced by an electron gun 3 consisting of a Wehnelt electrode and cathode. The cathode may be a filament of tungsten or alloy, for example tungsten-rhenium, having either a hairpin or a staple shape. Alternatively the cathode may be an indirectly heated activated dispenser cathode, which may be flat or of other geometry, for example a rod with a domed end. The dispenser cathode has the advantage of extended lifetime and increased mechanical strength. With a flat surface the dispenser cathode has the further advantage of requiring only an approximate degree of alignment in the Wehnelt electrode.

Primary focus is achieved by an anode at a suitable distance from the electron gun.

The electron beam 8 from the gun is centred in the X-ray tube 2 by a centring coil 14 or set of quadrupole lenses. Alternatively it may be centred by multipole lenses. Alternatively mechanical means may be used to centre the electron beam 8. The centring lens or coil

14 may be omitted, where the electron gun 3 is such that it produced an electron beam 8 which is sufficiently aligned within the tube 2.

The electron beam 8 is then focussed to a spot of varying diameter. Focussing down to a diameter of less than 5 μm or better may be achieved by an axial focussing lens 15 of the quadrupole, multipole or solenoid type.

The spot focus may be changed to a line focus with a stigmator lens 16, which may comprise a further set of quadrupole or multipole lenses. Lines with an aspect ratio of greater than 10:1 are possible. A line focus spreads the load on the target. When viewed at a suitable angle, the line appears as a spot.

The lenses 15, 16 are preferably magnetic, but may be electrostatic. All the lenses are electronically controlled, enabling remote control and continuous alignment and scanning of the focal spot. Change from spot to line focus and change of beam diameter are also controlled remotely by varying the control signals to the electron focussing devices 7.

The electronic control of the lenses enables the electron beam 8 to be defocussed and/or repositioned on the target 4. As a result, the high intensity focal spot of the electron beam 8 is not continuously being directed at one particular area of the target 4, which means that the rate of degradation of the target will be significantly slower than with known X-ray generators. The electron beam 8 is only focussed at high intensity when the X-ray beam is required.

The actions of defocussing and refocussing the electron

beam 8 are activated either at will by the operator by varying the power of the focussing coils, preferably by an electronic switch control, or automatically by the action of a shutter on the output side of the X-ray beam or other external event defined by the operator.

The target 4 is a metal, for example Cu, but it can be another material depending on the wavelength of the characteristic radiation required, for example Ag, Mo, Al, Ti, Rh, Cr, Co, Fe, W or Au. The target 4 is either perpendicular to the impinging electron beam 8, or may be inclined to decrease the absorption of the emitted X-rays.

In an example of a preferred embodiment of the present invention, the cathode is at negative high voltage and the electron gun 3 consists of a filament just inside the aperture 11 of a Wehnelt grid which is biased negatively with respect to the filament. The electrons are accelerated towards the anode which is at ground potential and pass through a hole in the latter and then through the tube 2 towards the target 4. Two sets of beam deflection coils 14, which may be iron-cored, are employed in two planes separated by 30 mm, mounted between the anode of the electron gun 3 and the focussing lens 15 to centre the beam. Between the focussing lens 15 and the target 4 is an air-cored quadrupole magnet which acts as a stigmator 16 in that it turns the circular cross-section of the beam 8 into an elongated one. This quadrupole 16 can be rotated about the tube axis so as to adjust the orientation of the line focus. The beam 8 can be moved about on the target surface 4 by controlling the currents in the four coils of the quadrupole 16.

With reference to Figs. 2 and 3 there is shown a tube

2, electron gun 3 and target 4, together with electron focussing means 7, which are discussed in more detail above. In the first focussed state, as shown in Fig. 2, the electron beam 8 is focussed by the focussing means 7 so that it forms a relatively small spot 20 on the target 4, the spot source being the required size for generation of X-rays for the intended purpose. In this state the X-ray generator is operational and the brightness of the emitted X-ray beam may be controlled by varying the applied power to the tube. When the generator is switched to the second unfocussed state as shown in Fig. 3, the electron beam 18 has the same power, but the focussing means does not focus the beam 18 so tightly, so that it forms a relatively larger spot source 21 on the target 4. In this state the X-ray generator is in standby mode and the intensity per unit area at the target 4 is greatly reduced. The consequent localised degradation of the target, which depends on local intensity per unit area, is also reduced.

With reference to Figs. 4 and 5 there is shown a tube 2, electron gun 3 and target 4, together with electron focussing means 7, which are discussed in more detail above. In the first focussed state, as shown in Fig. 4, the electron beam 28 is focussed by the focussing means 7 so that it forms a relatively small spot source 22 on the target 4, the spot source being the required size for generation of X-rays for the intended purpose. In this state the X-ray generator is operational and the brightness of the emitted X-ray beam may be controlled by varying the applied power to the tube. When the generator is switched to a second focussed state, as shown in Fig. 5, the electron beam 38 has the same power, but is focussed by the focussing means to a second spot source 23 on a different part of the target

4. The spot source 23 is the required size for generation of X-rays for the intended purpose, and will generally be he same size as the spot source 22 in the first state. There is no overlap between the positions of spot sources 22 and 23.

In practice there may be further operational states in which the spot source is the same size as spot sources 22, 23 but in different, non-overlapping locations. It may be possible to fit as many as ten or more non-overlapping sources on a target, thus giving a ten-fold increase in the life of the target. The focussing means 7 may be adjusted manually to move the spot source, or the control signals required to adjust the focussing means may be stored electronically, so that the apparatus automatically steps to the next state when an operator indicates that the position of the focus should be changed. The stepping could be automatic after a predetermined elapsed operating time at a particular state, for example an elapsed time counter could be built into the apparatus to show a warning signal when the predetermined operating time is exceeded. The operator would then be alerted to switch the apparatus to the next state.

Although the examples of Figs. 2 to 5 have been described with reference to spot sources, it is to be understood that the invention is equally applicable to line focus sources. Furthermore the illustrated embodiments have been described with a focussing means which comprises a centring lens, a focussing lens and a stigmator lens. It is to be understood that the functions of any of the three lenses may be combined in one or more lenses, and that the order of the components of the focussing means may be varied.

Figs. 6(a) and 6(b) shows schematically a side view and plan view respectively on a conventional sealed tube X-ray generator. The generator comprises a sealed vacuum enclosure 30 fabricated from glass and metal, or from ceramic and metal. Inside the enclosure 30 is an electron gun 31 and a target 32. Adjacent to the target are X-ray transparent windows 33, through which X-rays 36 are transmitted. Surrounding the vacuum enclosure between the electron gun 31 and target 32 is an electrostatic or electromagnetic lens. Behind the target is a conventional water cooling arrangement 35.

The lens comprises one or more sets of focussing coils 34 arranged outside the vacuum envelope of the X-ray tube 30. The coils 34 forming the lens may be electromagnetic or electrostatic. At least one of the sets of focussing coils 34 is used to steer the electron beam from the electron gun 31 onto the target 32, and may also be used to change the shape and/or size of the beam. A switch control (not shown) may be provided which upon operation automatically provides the electrical power to the coils 34 so as to steer the electron beam to a larger focus or to a different point on the target. This enables the power density loading on the target 32 to be reduced when the X-rays are not being used, or for new areas of the target 32 to be periodically exposed when the previously exposed area becomes damaged or degraded. In Fig. 6 the coils 34 are shown as being external to the vacuum. In this way it is possible for the focussing coils 34 to be retrofitted to an existing generator, in order to prolong the life of the generator. However the scope of the invention includes the case where the coils 34 are built in to the generator and provided inside the vacuum enclosure 30.

Figs. 7(a) and 7(b) shows schematically a side view and front view respectively on a conventional rotating anode X-ray generator. The generator comprises a continuously pumped vacuum chamber 40 containing an electron gun 41 and a target 42 deposited on a cylindrical anode 43 which rotates at high speed. Adjacent to the anode are X-ray transparent windows 44, through which X-rays 46 are transmitted. Surrounding the vacuum chamber between the electron gun 41 and target 42 is an electrostatic or electromagnetic lens. The anode 43 is water cooled (not shown). The rotation of the anode 43 dissipates more effectively the heat generated on the target 42, so that increased power loading of the target and hence increased X-ray brightness are possible.

The electrostatic or electromagnetic lens comprises one or more sets of focussing coils 45 arranged outside the vacuum chamber 40. The coils 45 serve the same purpose as the coils 34 described with reference to Fig. 6 above, and may also be retrofitted or fitted within the vacuum chamber, ie the coils may be internal or external.

These and other modifications and improvements can be incorporated without departing from the scope of the invention.

CLAIMS:

1. An X-ray generator comprising an electron gun, electron focussing means, a target and electronic control means, wherein the area of the target on which the focussing means causes electrons from said electron gun to impinge comprises an X-ray source, the control means being adapted to control the electron focussing means so that the X-ray source on said target may be varied in size and/or shape and/or position,

wherein the control means includes a switching means to switch the electron focussing means between a plurality of states, the X-ray source on said target having a particular size and/or shape and/or position in each of said plurality of states.

2. An X-ray generator according to Claim 1, wherein the control means includes a switching means to switch the electron focussing means between a first unfocussed state in which the X-ray source has a first area and a second focussed state in which the X-ray source has a second area smaller than said first area.

3. An X-ray generator according to Claim 2, wherein said first area has a surface area at least twice that of said second area.

4. An X-ray generator according to either Claim 2 or Claim 3, wherein said first area has a surface area at least four times that of said second area.

5. An X-ray generator according to any of Claims 2 to 4, wherein said first area has a surface area at

least ten times that of said second area.

6. An X-ray generator according to Claim 1, wherein the control means includes a switching means to switch the electron focussing means between a plurality of focussed states, whereby in each state the X-ray source is in a corresponding discrete position on said target.

7. An X-ray generator according to any preceding claim, wherein the electron gun comprises an evacuated tube, and wherein the electron focussing means comprises an x-y deflection system for centring the electron beam in the tube.

8. An X-ray generator according to any preceding claim, wherein the electron beam focussing means further comprises at least one electron lens.

9. An X-ray generator according to Claim 8, wherein said electron lens comprises an axially symmetric or round lens for focussing the electron beam to a line focus and for steering the electron beam.

10. An X-ray generator according to Claim 8, wherein said electron lens comprises at least one quadrupole or multipole lens for focussing the electron beam to a line focus and for steering the electron beam.

11. An X-ray generator according to any preceding claim, wherein the target is a metal selected from the group Cu, Ag, Mo, Rh, Al, Ti, Cr, Co, Fe, W, Au.

12. A method for extending the life of a target of an

X-ray generator, wherein the generator comprises an electron gun, electron focussing means and a target, the method comprising the steps of:

firing electrons at the target such that the area of the target on which the focussing means causes electrons from said electron gun to impinge comprises an X-ray source,

controlling the electron focussing means to move between a first unfocussed state in which the X-ray source has a first area and a second focussed state in which the X-ray source has a second area smaller than said first area, the intensity of electron impingement in the first state being sufficiently low to reduce target degradation, the intensity of electron impingement in the second state being sufficiently high such that the source produces a predetermined required level of brightness and source size on the target.

13. A method according to Claim 12, wherein the electron beam current is substantially the same in the first and second states, while the intensity of the beam per unit area at the target is lower in the first state than in the second state.

14. A method for extending the life of a target of an X-ray generator, wherein the generator comprises an electron gun, electron focussing means and a target, the method comprising the steps of:

firing electrons at the target such that the area of the target on which the focussing means causes electrons from said electron gun to impinge comprises an X-ray source,

controlling the electron focussing means to move between a plurality of focussed states, whereby in each state the X-ray source is in a

corresponding discrete position on said target, such that the intensity per unit area in each discrete position is substantially constant, and such that there is no overlap on the target between the discrete positions corresponding to each focussed state.

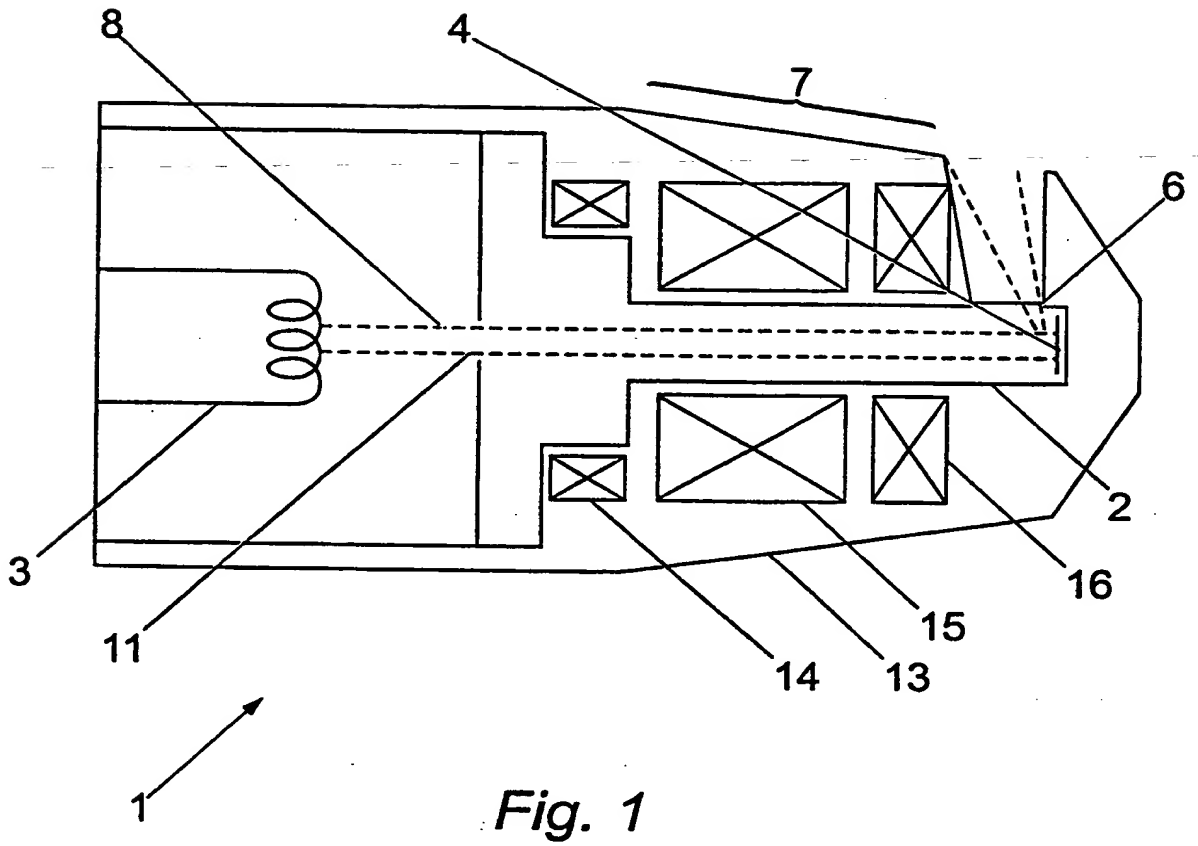


Fig. 1

Fig. 2

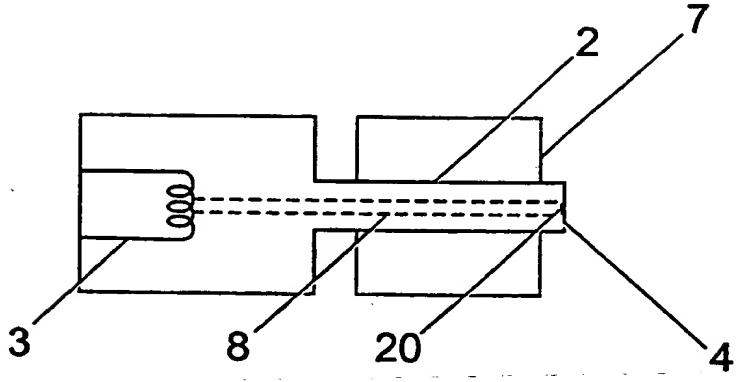


Fig. 3

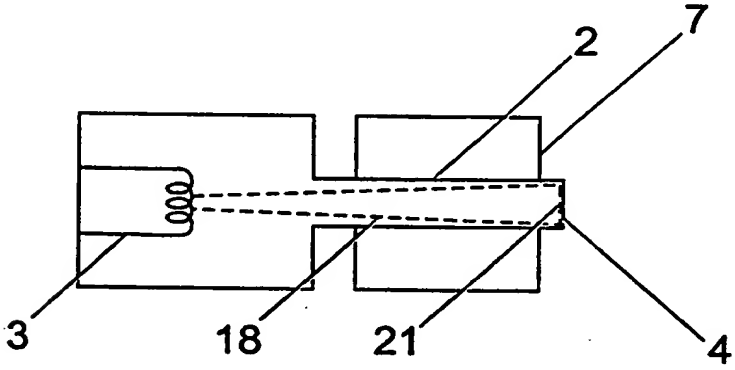


Fig. 4

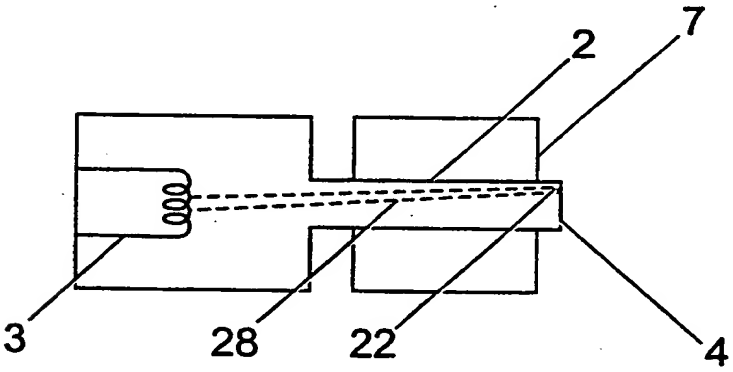
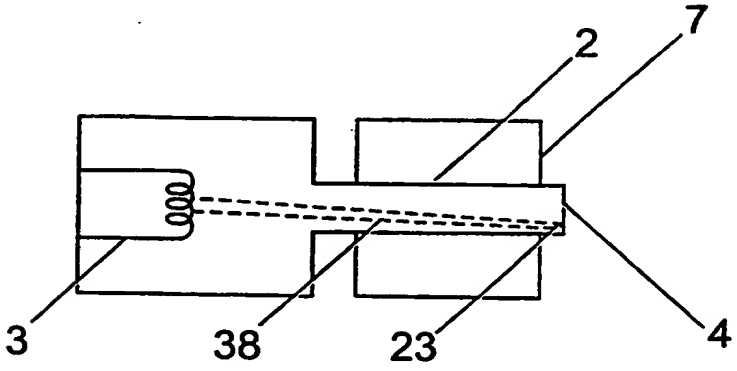


Fig. 5



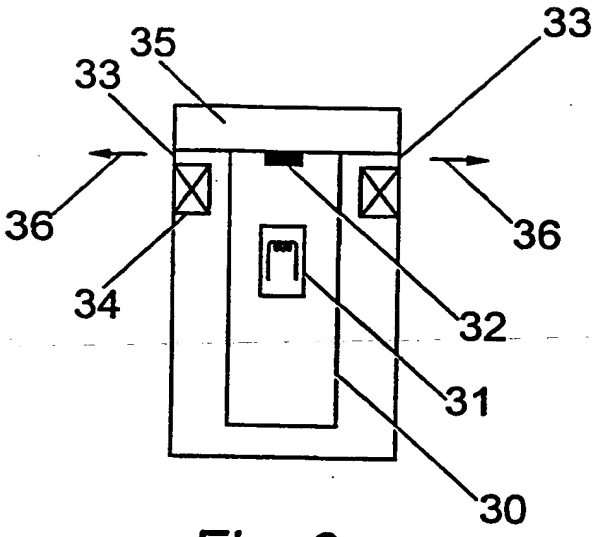


Fig. 6a

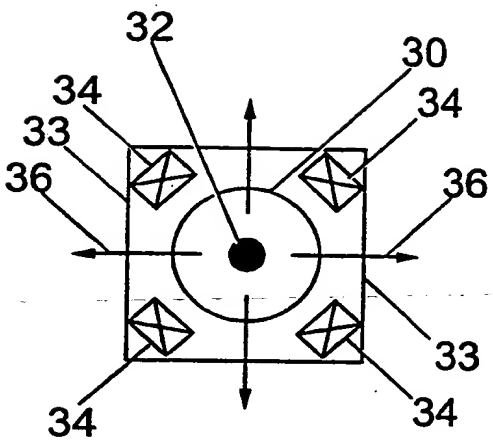


Fig. 6b

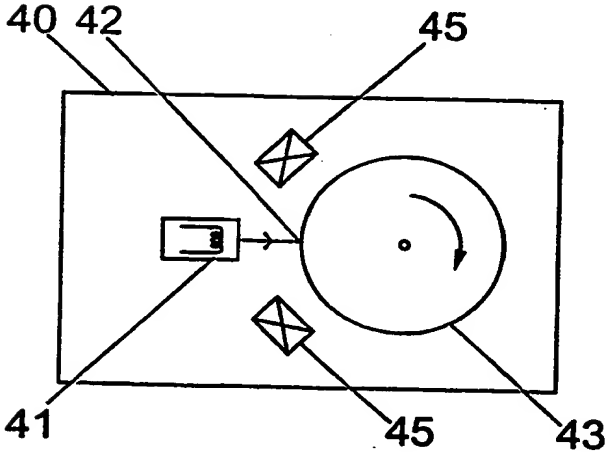


Fig. 7a

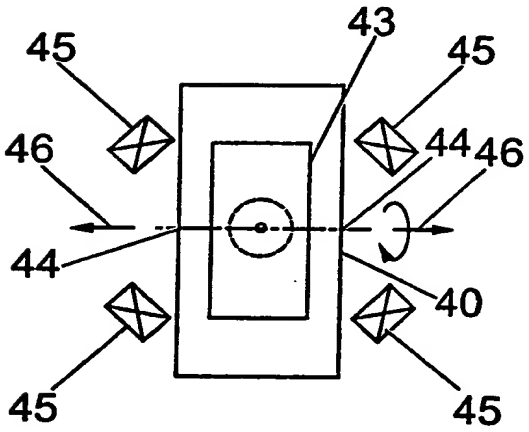


Fig. 7b

CLAIMS

1. An x-ray generator comprising an electron gun, electron focusing means, a target and electronic control means, wherein the area of the target on which the focusing means causes electrons from said electron gun to impinge comprises an x-ray source emitting an x-ray beam, the control means being adapted to control the electron focusing means so that the x-ray source on said target may be varied in size, wherein the x-ray generator further comprises a shutter to control the emitted x-ray beam, and wherein the control means includes a switching means to switch the electron focusing means between a first unfocused state in which the x-ray source has a first area upon action of the shutter and a second focused state in which the x-ray source has a second area smaller than said first area when the shutter is open.

2. An x-ray generator according to Claim 1, wherein said first area has a surface area at least twice that of said second area.

3. An x-ray generator according to Claim 1, wherein said first area has a surface area at least four times that of said second area.

4. An x-ray generator according to Claim 1, wherein said first area has a surface area at least ten times that of said second area.

5. An x-ray generator comprising an electron gun, electron focusing means, a target and electronic control means, wherein the area of the target on which the focusing means causes electrons from said electron gun to impinge comprises an x-ray source generating an x-ray beam output, the control means being adapted to control the electron focusing means so that the x-ray source on said target may be varied in size, wherein the control means includes a switching means to switch the electron focusing means between a plurality of focused states, whereby in each state the x-ray source is in a corresponding discrete stationary position on said target.

6. An x-ray generator according to any preceding Claim, wherein the electron gun comprises an evacuated tube, and wherein the electron focusing means comprises an x-y deflection system for centring the electron beam in the tube.

7. An x-ray generator according to any preceding Claim, wherein the electron beam focusing means further comprises at least one electron lens.

8. An x-ray generator according to Claim 7, wherein said electronic lens comprises an axially symmetric or round lens for focusing the electron beam to a line focus and for steering the electron beam.

9. An x-ray generator according to Claim 7, wherein said electron lens comprises at least one

12. A method according to Claim 11, wherein the electron beam current is substantially the same in the first and second states, while the intensity of the beam per unit area at the target is lower in the first state than in the second state.

13. A method of extending the life of a target of an x-ray generator, wherein the generator comprises an electron gun, electron focusing means and a target, the method comprising the steps of:

firing electrons at the target such that the area of the target on which the focusing means causes electrons from said electron gun to impinge comprises an x-ray source, and

controlling the electron focusing means to move between a plurality of focused states, whereby in each state the x-ray source is in a corresponding discrete stationary position on said target, such that the intensity per unit area in each discrete position is substantially constant, and such that there is no overlap on the target between the discrete positions corresponding to each focused state.

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